The Impact of Water Clarity on Home Prices in Vilas and Oneida Counties, Wisconsin[1]

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Abstract: This study estimates the residential property value gains associated with improvements in water clarity on 60 Northern Wisconsin lakes. Using a two-stage hedonic model applied to Wisconsin DNR water clarity data and data associated with 271 residential home sales obtained from Zillow.com and County property records. We conclude that a one (1) meter improvement in water clarity would produce a $8,090.87 – $32,171.12 improvement in the market price of an average residential property on a lake within the study area. We also conclude that in addition to water clarity the main non-housing attributes that drive property value in the region are the local tax rate and the distance to a public airport.

Introduction

There exist a significant number of lakes in Northern Wisconsin that exhibit low levels of water clarity. It is also a well-established fact that perceptions of water quality and water clarity have a significant bearing upon residential property values.[5] It is the case that an improvement in water clarity on those lakes that currently exhibit low clarity would result in a significant improvement in property values. (Not to mention a number of other economic benefits – such as increased tourism.) Rising property values also means increased property valuations and – potentially – local and State and local tax revenue. On the other hand, improving water clarity is not without costs. The matter is therefore a balancing act: In cases where the economic benefits exceed the costs associated with water clarity improvement there is a clear case to be made for said improvements.[6]

Vilas and Oneida Counties in Northern Wisconsin have, in total, well over 300 lakes that are greater than 100 acres in area. The two counties are sparsely populated with the majority of residents living directly on or very near a lake. The region is also distant from a metro area. The nearest -- Wausau, WI -- being roughly 62 miles away from Oneida County and

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[5] For examples see: Krysel, Boyer, Parson, and Welle (2003) or Kemp and Ng (2017).
[6] While there are certainly other measures of water quality (color, odor, bacteria, etc…) this study focuses solely upon water clarity and its economic impacts. This is not to suggest that these other measures are not important but that they are merely beyond the scope of this study.

one-hour drive time. It is safe to say that the lakes themselves, and the leisure activities associated with them, constitute a major economic driver for the region. Should the lakes not be properly maintained or damaged in some way it would result in significant economic loss to the area.

With this study, we seek to better understand the value increment likely to be associated with improvements in water clarity within these two counties. From this we are able to estimate a significant part of the likely economic benefits to both the private and public sector associated with improvements as well as the losses associated with deterioration of the lakes' water. It is our hope that that this will produce better informed and economically sound environmental remediation and an improvement in the already impressive natural resources of the State.

Outline of the Work

The work presented here may be said to be divided into four (4) parts. The first part introduces the study area and gives brief history of each of the sixty (60) lakes chosen for the study area.[7] Included within are a brief presentation of each lake are the size, depth, duration and method of monitoring, trophic state, remediation efforts, as well as the average clarity reading in 2017 (or most recent year). These are included to give the reader some idea about the lakes in study and the potential causes for their clarity levels.

The second section of the work covers the literature in the field and a theoretical discussion of the model used in this study. This section is included to give the interested reader an idea about the work that has already been done in this area as well as a very brief introduction to the type of models used to estimate the results. The third section is the application of the ideas presented in the previous section. This section covers the data sources – all of which are publicly available and free -- that were used to compile the dataset. We also present the working model developed including the rational for the specific variables included as well as the challenges posed by the available (or lack thereof) data.

The fourth portion of the study presents the study results. Readers who are primarily interested in the study results may wish to jump right to that section (pg. 30). In this section we cover the expected economic gains associated with improved water clarity to the private sector (residential property prices). Specific improvement values are given for each of the sixty lakes within the study area. Additionally, the data and formulae needed to calculate the direct economic effects are given. Using Anvil Lake in Vilas County, WI (Alphabetically the first lake in the study area) as an example we walk through how the reader, policy maker, or property owner – using our results -- can reasonably easily calculate the likely market price impact on their property or community from improvement (or reduction) in water clarity.
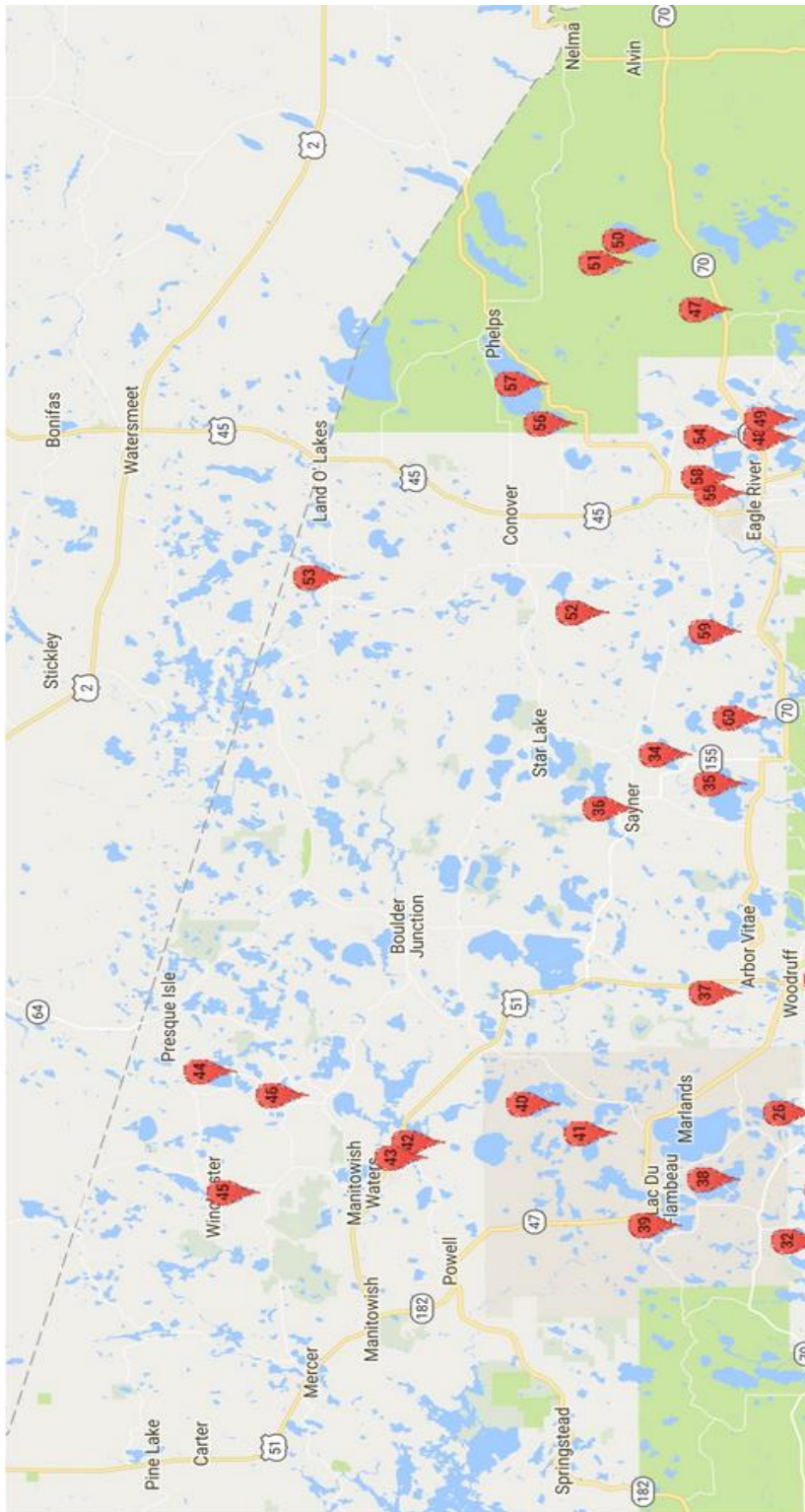
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[7] Lake information is taken directly from the Wisconsin Department of Natural Resources (DNR) (sources listed in text).

In the concluding section we review the two basic factors driving the marginal economic benefits associated with improved water clarity. These are, in order of importance, the existing level of clarity and the distance to the nearest public airport, which is we believe, a rough proxy of distance to city amenities such as grocery stores, parks, and restaurants. Our results show that property values improve with any improvement in water clarity on any of the lakes in the study area. That said the improvement in values (marginal change) is greatest on those lakes that currently have low levels of clarity and far distance from the nearest airport. In this way we provide a clear and straightforward method for understanding the areas in which the economic benefits can be expected to be the greatest.

The Study Area

Initially, 40 lakes in North Central Wisconsin were chosen for the study. This was later increased to 60 lakes in order to ensure sufficient sampling. It also should be noted that a several of the initial 40 lakes had to be dropped due to missing or insufficient data. This especially large number of lakes were chosen to ensure that a statistically significant number of properties could be obtained.

Sixteen of the lakes within the study area, Arrowhead Lake, Bass Lake, Big Arbor Lake, Big Fork Lake, Big Portage Lake, Brandy Lake, Bridge Lake, Dog Lake, Lake Nokomis, Lower Buckatabon Lake, Mercer Lake, Oneida Lake, Pioneer Lake, Pokegama Lake and Rest Lake had to be dropped from the study due to unavailability or the lack of water quality readings or a lack of recently sold properties information. We then added a number of lakes including Blue Lake, Buckskin Lake, Crawling Stone Lake, Fifth Lake, Flambeau Lake, Kawaguesage Lake, Killarney Lake, Lake Minocqua, Laurel Lake, Little Star Lake, Maple Lake, McCormick Lake, Oscar-Jenney Lake, Pickerel Lake, Spectacle Lake, Squaw Lake, Squirrel Lake, and White Sand Lake to the list of lakes. From this final set of lakes we were able to record data associated with 318 property sales. It should be noted that an unusually large number of properties had missing or erroneous data present on Zillow.com as well as other property listing sites. Where possible more accurate data was obtained from County property records, where it was not possible to do so the data was not used. Future researchers should be wary of this problem and verify data with official sources.

1	Hancock Lake		32	Squirrel Lake
2	Oscar-Jenny Lake		33	Buckskin Lake
3	Squash Lake		34	Lost Lake
4	Pelican Lake		35	Big Saint Germain Lake
5	George Lake		36	Plum Lake
6	Crescent Lake		37	Towanda Lake
7	Boom Lake		38	Crawling Stone Lake
8	Fifth Lake		39	Flambeau Lake
9	Killarney Lake		40	Ike Walton Lake
10	Tomahawk Lake		41	White Sand Lake
11	Spirit Lake		42	Manitowish Lake
12	Planting Ground Lake		43	Little Star Lake
13	Big Lake		44	Presque Isle Lake
14	Sugar Camp Lake		45	South Turtle Lake
15	Long Lake		46	Papoose Lake
16	Deer Lake		47	Anvil Lake
17	Indian Lake		48	Catfish Lake
18	Big Stone Lake		49	Cranberry Lake
19	Island Lake		50	Kentuck Lake
20	Maple Lake		51	Spectacle Lake
21	Laurel Lake		52	Upper Buckatabon Lake
22	Virgin Lake		53	Black Oak Lake
23	Little Fork Lake		54	Scattering Rice Lake
24	Two Sisters Lake		55	Yellow Birch Lake
25	Tom Doyle Lake		56	South Twin Lake
26	Shishebogama Lake		57	North Twin Lake
27	Minocqua Lake		58	Otter Lake Lake
28	Kawaguesaga Lake		59	Snipe Lake
29	Pickerel Lake		60	Little Saint Germain Lake
30	McCormick Lake			
31	Blue Lake			

The study was finalized with a larger number which are 60 lakes with 318 home properties (271 properties when outlier properties are excluded) sold during the period January 2014 to June 2018. The study set of lakes includes:

The Lakes

Hancock Lake (1.65 meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=1517900

Hancock Lake in Oneida County, Wisconsin has an area of 259 acres and a maximum depth of 22 feet. It has been monitored by volunteers since 2005 most recent readings were taken by William Tischendorf and other data collectors. The lake has not undergone any remediation efforts.

Oscar-Jenny Lake (1.65 meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=1009100

Oscar-Jenny Lake in Oneida County, Wisconsin has an area of 101 acres and a maximum depth of 24 feet. It is monitored by volunteers. The lake's water is reported as being 'moderately clear'. The lake has not undergone any remediation efforts.

Virgin Lake (1.21 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=1614100

Virgin Lake in Oneida County, Wisconsin has an area of 261 acres and a maximum depth of 31 feet. It has been monitored by volunteers since 1994—most recently by Lynn Zibill. The lake's water is reported as being 'moderately clear'. The lake has not undergone any remediation efforts and lost clarity over the period 2015 - 2017.

Anvil Lake (3.6 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=968800

Anvil Lake in Vilas County, Wisconsin has an area of 377 acres and a maximum depth of 32 feet. It has been monitored by volunteers since 1986 – most recently by Ingrid Stephan and Tim Meyer. The lake's water is reported as being 'moderately clear'. The lake has not undergone any remediation efforts.

Catfish Lake (1.38 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=1603700

Catfish Lake in Vilas County, Wisconsin has an area of 978 acres and a maximum depth of 30 feet. It has been monitored by volunteers from 1993 – recently by Dan Cibulka. The lake's water is reported as being 'low clarity'. The lake has not undergone any remediation efforts to improve clarity.

Cranberry Lake (1.3 Meters)

https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=1603800

Cranberry Lake in Oneida County, Wisconsin has an area of 924 acres and a maximum depth of 23 feet. It has been monitored by volunteers since 1992 – most recently by Carole Linn. The lake's water is reported as being 'low clarity'. The lake has not undergone any remediation efforts to improve clarity.

Figure 1. Cranberry lake (source: www.realtor.com)

Kentuck Lake (2.63 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=716800

Kentuck Lake in Vilas County, Wisconsin has an area of 1001 acres and a maximum depth of 40 feet. It has been monitored by volunteers since 1986 – most recently by Brenton Butterfield, Jane Bonkoski, and Maribeth Park. Lake Kentuck is part of the Wisconsin DNR's long term lake monitoring project. The lake's water is reported as being 'low clarity'. The lake has not undergone any remediation efforts to improve clarity. Water clarity improved significantly from 2014 – 2017.

Figure 2. Kentuck Lake (source: Kentuck Lake District www.kentucklakedistrict.org)

Spectacle Lake (2.47 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=717400

Spectacle Lake in Vilas County, Wisconsin has an area of 166 acres and a maximum depth of 42 feet. It has been monitored by volunteers since 1986 – most recently by Jim Wildenberg. The lake's water is reported as being 'moderately clear'. The lake has not undergone any remediation efforts to improve clarity.

Little Saint Germain Lake (1.43 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=1596300

Little Saint Germain Lake in Vilas County, Wisconsin has an area of 972 acres and a maximum depth of 53 feet. It has been monitored by volunteers since 1990 – most recently by George Jackson. The lake's water is reported as being 'low clarity'. The lake has not undergone any remediation efforts to improve clarity.

Lost Lake (1.5 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=1575100

Lost Lake in Oneida County, Wisconsin has an area of 160 acres and a maximum depth of 18 feet. The lake's water is reported as being 'low clarity'. The lake has not undergone any remediation efforts to improve clarity.

Upper Buckatabon Lake (2.05 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=1621800

Upper Buckatabon Lake in Vilas County, Wisconsin has an area of 493 acres and a maximum depth of 47 feet. It has been monitored by volunteers since 1993 – most recently by Art Ekberg and Dan Benson. The lake's water is reported as being 'moderately clear'. The lake has not undergone any remediation efforts to improve clarity. Water clarity has deteriorated over the period 2015 – 2017.

Figure 3. Upper Buckatabon lake (source: www.zillow.com)

Manitowish Lake (2.9 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=2329400

Manitowish Lake in Vilas County, Wisconsin has an area of 496 acres and a maximum depth of 61 feet. It has been monitored by volunteers from 1992 to 1998 and again since 2016. The lake has not undergone any remediation efforts to improve clarity.

Figure 4. Manitowish lake (source: Vilas County www.vilaswi.com)

Little Star Lake (4.26 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=2334300

Little Star Lake in Vilas County, Wisconsin has an area of 260 acres and a maximum depth of 67 feet. It has been monitored by volunteers from 1994 to 2009 and again since 2015. The lake has not undergone any remediation efforts to improve clarity.

Tomahawk Lake (5.38 Meters)
https://dnr.wi.gov/lakes/LakePages/LakeDetail.aspx?wbic=1542700

Tomahawk Lake in Oneida County, Wisconsin has an area of 3462 acres and a maximum depth of 84 feet. It has been monitored by volunteers since 1992 – most recent readings were taken by Steven Cote and other data collectors. The lake's water is reported as being 'very clear'. The lake has not undergone any remediation efforts to improve clarity.

Figure 5. Tomahawk lake

Little Fork Lake (1.56 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=1610600

Little Fork Lake in Oneida County, Wisconsin has an area of 336 acres and a maximum depth of 34 feet. It has been monitored by volunteers since 1993—most recently by Henry Schwiesow. The lake's water is reported as being 'moderately clear'. The lake has not undergone any remediation efforts to improve clarity.

Island Lake (2.5 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=2334400

Island Lake in Vilas County, Wisconsin has an area of 865 acres and a maximum depth of 35 feet. It has been monitored by volunteers since 1993– most recent readings were taken by Paul Lehmkuhl. The lake's water is reported as being 'moderately clear'. The lake has not undergone any remediation efforts to improve clarity.

Long Lake (3.79 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=1609000

Long Lake in Oneida County, Wisconsin has an area of 604 acres and a maximum depth of 31 feet. It has been monitored by volunteers since 1993 – most recent readings were taken by Fred Knoch and other data collectors. The lake's water is reported as being 'low clarity'. The lake has not undergone any remediation efforts to improve clarity.

Lake Minocqua (4.96 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=1542400

Minocqua Lake in Oneida County, Wisconsin has an area of 1339 acres and a maximum depth of 60 feet. It has been monitored by volunteers since 1989—most recently by John Gray. The lake is also part of the DNR's long term lake monitoring project. The lake's water is reported as being 'moderately clear'. The lake has not undergone any remediation efforts to improve clarity.

Figure 6. Minocqua lake (source: Minocqua/ Kawaguesaga lakes protection association http://minocquakawaga.org)

Figure 7. Minocqua lake

Pelican Lake (1.34 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=1579900

Pelican Lake in Oneida County, Wisconsin has an area of 3545 acres and a maximum depth of 39 feet. It has been monitored by volunteers since 1987 – most recent readings were taken by Dava Hardt, Alan Wirt, and Ty Krajewski. The lake is also part of the DNR's long term lake monitoring project. The lake's water is reported as being 'low clarity'. The lake has not undergone any remediation efforts to improve clarity.

Two Sisters Lake (2.44 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=1588200

Two Sisters Lake in Oneida County, Wisconsin has an area of 719 acres and a maximum depth of 63 feet. . It has been monitored by volunteers since 1986—most recently by Kent Bradshaw. The lake has not undergone any remediation efforts to improve clarity.

Spirit Lake (3.35 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=1612000

Spirit Lake in Oneida County, Wisconsin has an area of 348 acres and a maximum depth of 39 feet. It has been monitored by volunteers since 1987 – most recent readings were taken by John Lake and Phil Burnside. The lake's water is reported as being 'very clear'. The lake has not undergone any remediation efforts to improve clarity

Planting Ground Lake (4 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=1609100

Planting Ground Lake in Oneida County, Wisconsin has an area of 1010 acres and a maximum depth of 37 feet. It has been monitored by volunteers since 1989 – most recent readings were taken by Lloyd Rossa. The lake's water is reported as being 'low clarity'. The lake has not undergone any remediation efforts to improve clarity.

Tom Doyle Lake (1.48 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=1586800

Tom Doyle Lake in Oneida County, Wisconsin has an area of 108 acres and a maximum depth of 30 feet. It has been monitored by volunteers since 1973—most recently by Karyl Rosenberg. The lake's water is reported as being 'low clarity'. The lake has not undergone any remediation efforts to improve clarity.

Shishebogama Lake (2.8 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=1539600

Shishebogama Lake in Oneida and Vilas County, Wisconsin has an area of 700 acres and a maximum depth of 42 feet. It has been monitored by volunteers since 1990 – most recently by Robert Schultz. The lake's water is reported as being 'moderately clear'. The lake has not undergone any remediation efforts to improve clarity. The Water Clarity of the Lake improved significantly from 2016 – 2017.

Big Lake (1.01 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=1613000

Big Lake in Oneida County, Wisconsin has an area of 845 acres and a maximum depth of 27 feet. It has been monitored by volunteers since 1990 – most recent readings were taken by Kelvin Kobernick and other data collectors. The lake's water is reported as being 'low clarity'. The lake has not undergone any remediation efforts to improve clarity.

Big Saint Germain (2.09 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=1591100

Big Saint Germain Lake in Vilas County, Wisconsin has an area of 1622 acres and a maximum depth of 42 feet. It has been monitored by volunteers since 1989 – most recently by joe Koschnik, and Don and Marie Bauman. The lake's water is reported as being 'low clarity'. The lake has not undergone any remediation efforts to improve clarity.

Big Stone Lake (1.05 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=1612200

Big Stone Lake in Oneida County, Wisconsin has an area of 607 acres and a maximum depth of 57 feet. It has been monitored by volunteers since 1993 – most recent readings were taken by Nancy Jensen and Ed Cottingham. The lake's water is reported as being 'low clarity'. The lake has not undergone any remediation efforts to improve clarity.

Black Oak Lake (6.7 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=1630100

Black Oak Lake in Vilas County, Wisconsin has an area of 564 acres and a maximum depth of 85 feet. It has been monitored by volunteers since 2002 – most recently by Walt Bates. The lake's water is reported as being 'very clear'. Several studies have been completed to better understand the source of the water clarity and develop methods to maintain it.

Blue Lake (1.02 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=1538600

Blue Lake in Oneida County, Wisconsin has an area of 441 acres and a maximum depth of 49 feet. It has been monitored by volunteers since 1993—most recently by Richard Johnson, Janine Myers, Dan Pagel, and Sue Pagel. The lake's water is reported as being 'very clear'.

Boom Lake (1.05 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=1580200

Boom Lake in Oneida County, Wisconsin has an area of 365 acres and a maximum depth of 30 feet. It has been monitored by volunteers since 1997 – most recent readings were taken by Robert Young. The lake's water is reported as being 'low clarity'. The lake has not undergone any remediation efforts to improve clarity. The water clarity has deteriorated during the period 2014 – 2017.

Buckskin Lake (2.7 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=2272600

Buckskin Lake in Oneida County, Wisconsin has an area of 642 acres and a maximum depth of 22 feet. The lake's water is reported as being 'low clarity'. There exists a 'Buckskin Lake Improvement Association' dating back to 1982 but information about current work was not available.

Crawling Stone Lake (4.6 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=2322800

Crawling Stone Lake in Vilas County, Wisconsin has an area of 1483 acres and a maximum depth of 87 feet. It has been monitored by volunteers since 2004 – Most recently by Edith Dobrinski and Ralph Kerler. The lake's water is reported as being 'very clear'.

Crescent Lake (2.06 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=1564200

Crescent Lake in Oneida County, Wisconsin has an area of 616 acres and a maximum depth of 32 feet. It has been monitored by volunteers since 1986 – most recent readings were taken by Alan Janssen and other data collectors. The lake's water is reported as being 'moderately clear'. Although several efforts have been made to minimize the number of invasive species, the lake has not undergone any remediation efforts to improve clarity. Water clarity has deteriorated during the study period 2014 – 2018.

Deer Lake (1.2 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=1612300

Deer Lake in Oneida County, Wisconsin has an area of 188 acres and a maximum depth of 20 feet. It has been monitored by volunteers since 1988 – most recent readings were taken by Ed Cottingham. The lake's water is reported as being 'low clarity'. The lake has not undergone any remediation efforts to improve clarity.

Fifth Lake (0.73 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=1571100

Fifth Lake in Oneida County, Wisconsin has an area of 238 acres and a maximum depth of 9 feet. It has been monitored by volunteers since 2005 – most recent readings were taken by Scott Patulski and Kris Krause. The lake's water is reported as being 'moderately clear'. The lake has not undergone any remediation efforts to improve clarity.

Yellow Birch Lake (1.36 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=1599600

Yellow Birch Lake in Vilas County, Wisconsin has an area of 192 acres and a maximum depth of 23 feet. It has been monitored by volunteers since 1993 – most recently by Jerome Plocinski and Dan Vladic. The lake's water is reported as being "low" clarity. The lake has not undergone any remediation efforts to improve clarity.

White Sand Lake (4 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=2321100

White Sand Lake in Vilas County, Wisconsin has an area of 1181 acres and a maximum depth of 63 feet. The lake has been monitored most recently by William Tischedorf. The lake's water is reported as being "very clear" clarity. The lake has not undergone any remediation efforts to improve clarity.

Towanda Lake (3.1 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=1022900

Towanda Lake in Vilas County, Wisconsin has an area of 139 acres and a maximum depth of 27 feet. It has been monitored by volunteers since 1992—most recently by Yolan Mistele. The lake's water is reported as being "moderately clear" clarity. The lake has not undergone any remediation efforts to improve clarity.

Squirrel Lake (2.75 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=1536300

Squirrel Lake in Vilas County, Wisconsin has an area of 1309 acres and a maximum depth of 46 feet. It was monitored by volunteers between 1986 and 2015 – Most recently by Ben Niffenegger. The lake's water is reported as being "low" clarity. The lake has not undergone any remediation efforts to improve clarity.

Squaw Lake (1.16 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=2271600

Squaw Lake in Vilas County, Wisconsin has an area of 736 acres and a maximum depth of 21 feet. It has been monitored by volunteers since 1999 – Most recently by Bob Sundell, Jerry Mroczkowski, and Issac Kruger. The lake's water is reported as being "low" clarity. The lake has not undergone any remediation efforts to improve clarity.

Squash Lake (5.5 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=1019500

Squash Lake in Oneida County, Wisconsin has an area of 398 acres and a maximum depth of 74 feet. It has been monitored by volunteers since 1989 – most recent readings were taken by Marj Mehring and other data collectors. The lake's water clarity is reported as being "very clear". The lake has not undergone any remediation efforts to improve clarity.

South Twin Lake (3.12 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=1623700

South Twin Lake in Vilas County, Wisconsin has an area of 628 acres and a maximum depth of 43 feet. It has been monitored by volunteers since 1993 – Most recently by Dave Selby. The lake's water is reported as being "moderately clear" clarity. The lake has not undergone any remediation efforts to improve clarity.

South Turtle Lake (1.97 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=2310200

South Turtle Lake in Vilas County, Wisconsin has an area of 466 acres and a maximum depth of 40 feet. It has been monitored by volunteers since 1991 – most recently by John and Susan Breiten and Jo Barlament. The lake's water's clarity is reported as being "low" clarity. The lake has not undergone any remediation efforts to improve clarity.

Flambeau Lake (5.68 Meters)
https://dnr.wi.gov/lakes/LakePages/LakeDetail.aspx?wbic=2320500&page=more

Flambeau Lake in Vilas County, Wisconsin has an area of 1166 acres and a maximum depth of 78 feet. It has been monitored by volunteers since 2011 – Most recently by Tom Skonie. The lake has not undergone any remediation efforts to improve clarity.

George Lake (1.06 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=1569600

George Lake in Oneida County, Wisconsin has an area of 443 acres and a maximum depth of 26 feet. It has been monitored by volunteers since 1991 – most recent readings were taken by Stephanie Boismenue and Abbi Bowman. The lake's water's clarity is reported as being "low" clarity. The lake has not undergone any remediation efforts to improve clarity.

Indian Lake (2.9 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=1598900

Indian Lake in Oneida County, Wisconsin has an area of 354 acres and a maximum depth of 26 feet. It has been monitored by volunteers since 1986 – most recent readings were taken by Joseph Smogar and other data collectors. The lake's water's clarity is reported as being "moderately clear". The lake has not undergone any remediation efforts to improve clarity.

Kawaguesaga Lake (3.48 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=1542300

Kawaguesaga Lake in Oneida County, Wisconsin has an area of 700 acres and a maximum depth of 44 feet. It has been monitored by volunteers since 2000 – Most recently by John Gray, Regis Brost, and Darien Brost. The lake's water's clarity is reported as being "moderately clear". There have been multiple efforts to improve lake water clarity. Water clarity has deteriorated over the study period 2014 – 2017.

Killarney Lake (0.7 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=1520900

Killarney Lake in Oneida County, Wisconsin has an area of 293 acres and a maximum depth of 8 feet. It has been monitored by volunteers since 1996 – most recent readings were taken by Brian Hager. The lake's water's clarity is reported as being "low clarity". The lake has not undergone any remediation efforts to improve clarity.

Laurel Lake (0.75 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=1611800

Laurel Lake in Oneida County, Wisconsin has an area of 249 acres and a maximum depth of 27 feet. It has been monitored by volunteers since 1993-- most recently by Phil Burnside. The lake's water's clarity is reported as being "low clarity". The lake has not undergone any remediation efforts to improve clarity.

Maple Lake (4.3 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=1609900

Maple Lake in Oneida County, Wisconsin has an area of 131 acres and a maximum depth of 15 feet. It has been monitored by volunteers since 1991 – most recent readings were taken by Ken Zator. The lake's water's clarity is reported as being "moderately clear". The lake has not undergone any remediation efforts to improve clarity.

McCormick Lake (0.6 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=1526600

McCormick Lake in Oneida County, Wisconsin has an area of 113 acres and a maximum depth of 8 feet. It has been monitored by volunteers since 2016 -- most recently by Stephanie Boismenue and Aubrey Nycz. The lake has not undergone any remediation efforts to improve clarity.

North Twin Lake (8.7 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=1623800

Twin Lakes (combined with South Twin Lake) in Vilas County, Wisconsin has an area of 2871 acres and a maximum depth of 60 feet. It has been monitored by volunteers since 1993 – most recently by Dave Selby. The lake's water's clarity is reported as being "moderately clear". There have been multiple efforts to improve lake water clarity. Water clarity has improved significantly during the study period 2014 – 2017.

Otter Lake (0.9 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=1600100

Otter Lake in Vilas County, Wisconsin has an area of 174 acres and a maximum depth of 30 feet. It has been monitored by volunteers since 1993- Most recently by Dave Mueller. The lake's water's clarity is reported as being "low clarity". The lake has not undergone any remediation efforts to improve clarity.

Papoose Lake (3 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=2328700

Papoose Lake in Vilas County, Wisconsin has an area of 422 acres and a maximum depth of 65 feet. It has been monitored by volunteers since 1993—most recently by Howard

Feddema. The lake's water's clarity is reported as being "very clear". The lake has not undergone any remediation efforts to improve clarity.

Pickerel Lake (1.62 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=1590400

Pickerel Lake in Oneida County, Wisconsin has an area of 581 acres and a maximum depth of 17 feet. It has been monitored by volunteers since 2001 – most recently by Michael Roach. The lake's water's clarity is reported as being "low clarity". The lake has not undergone any remediation efforts to improve clarity.

Plum Lake (2.94 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=1592400

Plum Lake in Vilas County, Wisconsin has an area of 1057 acres and a maximum depth of 57 feet. It has been monitored by volunteers since 1990—most recently by Robert Marshall. The lake's water's clarity is reported as being "moderately clear". There have been multiple efforts to improve lake water clarity.

Presque Isle Lake (7.35 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=2956500

Presque Lake in Vilas County, Wisconsin has an area of 1165 acres and a maximum depth of 103 feet. It has been monitored by volunteers since 1989 – most recently by Richard Lathrop. The lake's water's clarity is reported as being "very clear". There have been multiple efforts to improve lake water clarity.

Scattering Rice Lake (2.4 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=1600300

Scattering Rice Lake in Vilas County, Wisconsin has an area of 263 acres and a maximum depth of 17 feet. It has been monitored by volunteers since 1994 – Most recently by Jim Nelson and Howard Feddema. The lake's water's clarity is reported as being "low clarity". There have been multiple efforts to improve lake water clarity. (It is worth noting that there have been significant improvements in clarity readings in recent years.)

Snipe Lake (2.4 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=1018500

Snipe Lake in Vilas County, Wisconsin has an area of 216 acres and a maximum depth of 15 feet. It has been monitored by volunteers since 1995 – most recently by Don Osterberg. The lake's water's clarity is reported as being "moderately clear". The lake has not undergone any remediation efforts to improve clarity.

Sugar Camp Lake (3.7 Meters)
https://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=1020400

Sugar Camp Lake in Oneida County, Wisconsin has an area of 519 acres and a maximum depth of 38 feet. It has been monitored by volunteers since 1995 – most recent readings were taken by Otto Schoeneck and other data collectors. The lake's water's clarity is reported as being "very clear". The lake has not undergone any remediation efforts to improve clarity. Water clarity has improved significantly during the study period 2016 – 2018.

Literature

There is a long -- but narrow -- set of literature on the economic value of water clarity stretching back to the 1960's. The issue that appears repeatedly in the early literature is the question of the best measure of water quality. That is, is it quality or clarity a better determinant of property values? If it is clarity that matters, are subjective or objective measures better?

Early papers by David (1968) and Epp and Al-Ani (1979) used subjective valuations of water clarity to measure the impacts on property prices. The earlier study by David used a simple rating of good, moderate, and poor convey water quality. These were then added to other property attributes in a simple hedonic model to determine the impact of water clarity upon property prices. David's study found that people's perceptions regarding water clarity has a significant impact upon property prices. The later study completed by Epp and Al-Ani focused on the impact of river water clarity on property prices. The authors found that although water clarity did have bearing upon property prices – but only in terms of a decrease in quality. That is, a perceived decline in quality caused prices to fall but a perceived improvement in quality did not cause prices to rise. The authors did however find a consistent correlation between water acidity (as measured by pH) and property prices. Thus, raising an interesting distinction between the perception of water quality and water quality itself.

This trend in the literature continues with the study done by Brashares (1985). Using a hedonic model, this study focused on a large number of lakes in Southern Michigan and used eight different measures of water quality. The author found that only turbidity (an objective measure of clarity – similar to that used in this study) and fecal coliform had a significant impact upon property prices. The author concluded that although perception of water clarity does impact property prices these are most effectively captured with objective – rather than subjective – measures.

A number of studies have focused specifically on the question of using objective versus subjective measures of value and between perception (clarity) of quality and actual water quality in measuring water quality. A study by Steinnes (1992) found that it is the perception of water quality (clarity) rather than actual water quality that has the most significant bearing upon property values suggesting that subjectivity was an important factor. A later paper by Poor et.al. (2001) found that there existed significant differences

between the economics values produced using subjective measures of water clarity when compared to using objective measures. In that study the authors found that subjective measures tended to under report water clarity when compared to objective measure (such as Secchi disk readings).

The specific model developed in this study is derived from Michael, Boyle, and Bouchard (1996). Using a hedonic model and data from a set of lakes in Maine this study demonstrated the effect of water clarity on lakefront property prices. In additional to the customary locational and structural variables the authors used Secchi disk readings as an objective measure of water clarity. In developing the model clarity data was converted into log form to in order to better represent willingness to pay for improved water. That is, to convey that individuals are likely to pay more for an improvement of 1 to 4 feet of water clarity than for an improvement of 21 to 24 feet of clarity. (Both being an improvement of 3 feet.) The authors concluded that about 15% of the property value on the lakes in the study area was the result of water quality. They further concluded that an improvement of an additional one (1) meter of clarity would roughly double the value associated with water quality on property prices. In terms of total property prices their study suggested about a 15% improvement in the sale price of property adjacent to the lake.

Subsequent studies by Boyle et.al (1998); Krysel, Boyer, Parson, and Welle (2003); and Kemp and Ng (2017), have used models very similar to the one described above. The results achieved by these studies produced similar results with a rough doubling of the value attributable to water clarity being associated with an improvement of an additional 1 meter of clarity (for those lakes with low initial water clarity. Indeed, it would not be too much to say that the use of hedonic models combined with objective measures of water clarity (rather than quality) have become the 'industry standard' when attempting to uncover the implicit value of water clarity on property prices.

Method - Hedonic Modeling

Hedonic Modeling is a commonly used technique used to estimate the value of a specific attribute within a larger set of attributes associated with a specific commodity.[8] The most common usages include estimating the value of property improvements, the impact of public space on private property, and the value of environmental attributes associated with a given commodity on their prices. Using these models, a researcher can isolate and analyze the marginal value associated with each attribute of a given property. If desired, the additional step can be taken to create a hypothetical situation in order to determine the economic benefit of making a change to that attribute. This can then be weighed against the costs associated with making the change to test the economic feasibility of the project.

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[8] See Monsoon (2009) or Malpezzi (2012) for a recent, more complete overview of the uses of hedonic modeling.

Regression analysis is the specific statistical technique that serves as the foundation for hedonic modeling. For studies that seek to determine the value of a specific environmental attribute such as this this basic form of the regression generally looks like;

$P = f(S,L,E)$
Where,

> P = Sale Price of the Property
> S = A Vector of Structural Attributes
> L = A Vector of Locational Attributes
> E = A Vector of Environmental Attributes

From the estimated coefficients on each of the attributes within of the vectors we can develop an idea about the marginal value of each of those attributes. This regression output is commonly referred to as the fundamental hedonic equation. In more sophisticated studies (such as the one presented here) this is referred to as the 'first stage' equation. Attributes with estimates negative coefficients have a negative impact on property prices while attributes with positive estimated coefficients have a positive effect upon property prices. Thus, we would expect the estimated coefficient for water quality to have a positive coefficient. Conversely, we would expect the estimated coefficient on the local tax rate to be negative.

The 'second stage' equation is derived from the first. This second stage creates a hypothetical 'demand curve' or willingness to pay for the attribute in question. By summing the estimated constant as well as the mean value of all variables times their estimated coefficients (excluding the variable we wish to focus on) we are able to create a statistical picture of the average property – as if the focus attribute did not exist. If we wish to create a statistical picture of the average property with the observed focus attribute we can add in the mean value of that attribute times its estimated coefficient. If we wish to test the impact of an alteration to the focus attribute we can add the altered value times the previously estimated coefficient to the 'average property created previously.

Data Sources

Water clarity data was obtained using Wisconsin DNR reports for 60 Northern Wisconsin Lakes.[9] Average annual reported clarity readings in the year the house was sold we used to estimate the current water clarity level at the time the house was sold. For those houses sold during the winter months clarity readings from the previous summer were used. These reports are available free to the public and, in many cases, date back several years. Reports are published several times a year at irregular intervals for most lakes and include data on water clarity as well as a host of other information. Water clarity data is collected and reported in multiple ways. For our purposes we use the reported objective measure – Secchi Disk readings. Secchi disks are used to measure the maximum water depth at which an object may be observed from the surface.
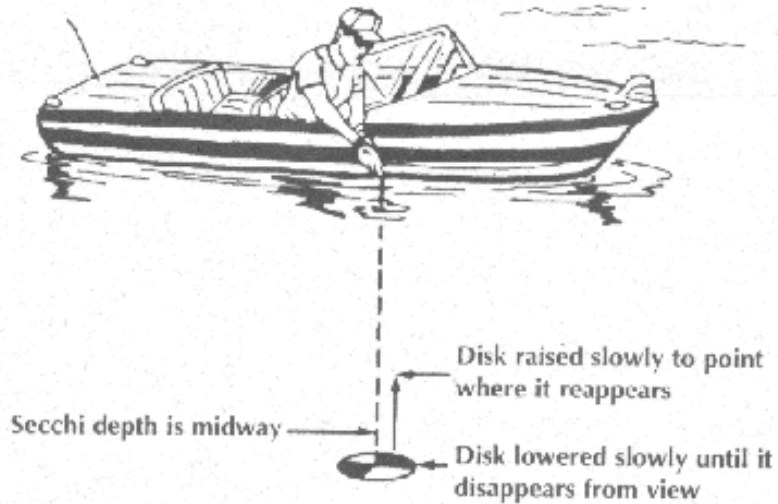
Figure 5 Taking a Secchi Disk Reading

Housing sale prices and attributes were taken from the website Zillow.com. To the extent possible these were confirmed using Vilas and Oneida County data. Where discrepancies between the two were noted the transaction was excluded from the dataset. The prices and attributes of all houses and vacant properties sold in the years 2014-2018 (June) over the study area were used. Distances to the nearest public airport and emergency rooms were calculated using the 'fastest driving route' in google maps.

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[9] Reports available at http://dnr.wi.gov/lakes/waterquality/
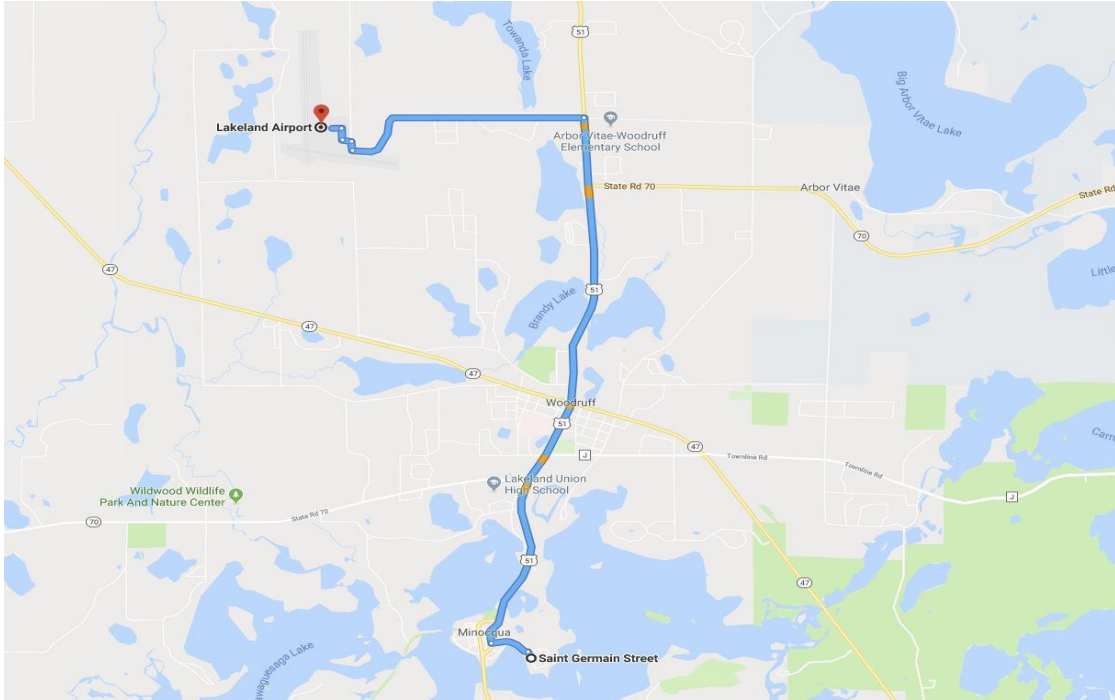
Figure 9. The distance from Minocqua lake to the nearest public airport

In sum, data was gathered on the following structural attributes,

- Square meters of living area (zero for empty lots)
- Sale Date
- Lake Frontage
- Fireplace
- Heat
- Basement
- Bathrooms
- Bedrooms
- Deck
- Garage
- Lot Size Hectares

The following locational attributes,

- Local Tax Rate
- Distance from a Public Airport
- Distance from an Emergency Room
- Lake Area
- Water Clarity (Linear)
- Water Clarity (Log)

A few things should be noted: It would be possible to develop a longer list of attributes for the given set of properties however it would not assist us in finding the specific value of water clarity – the focus of this study. Second, where the specific attributes of a listing were unknown the site was assumed to not have said attribute. For example, if no fireplace was mentioned in the listing a value of zero was assigned to that listing (binary variable) for that attribute. For properties that were simply a vacant lot all structural variables were assigned a value of zero.

The Model

This study uses the inflation corrected sale price of the property as the dependent variable.[10] That is, it is the determinants of residential property sale price that we are seeking to explain. Although other studies have done so we did not adjust sale price for variations in lake frontage, e.g., sale price/frontage. Although we did test sale price/frontage, the results turned out to be clearly inferior in terms of the model's ability to forecast prices. It seems likely that this is due to the low variation in frontage. (Most properties within the study area have between 100 and 120 feet of frontage.)

We ran three separate linear regressions in sets of twos. In order to get a rough idea about variable relationships we first ran a regression on the full dataset including a linear measure of water clarity. Specifically, we were interested in the degree of impact that existing water clarity was having upon real estate prices. Reasonably satisfied with the initial results we ran a second regression on the full dataset with water clarity converted to a log format. This was done to under the assumption that the willingness to pay for improved water clarity is not a linear but rather something like a log relationship. That is, people will pay a more for the first 1 – 2 meters of clarity than they would for the 4th or 5th meter of clarity.

Noticing that we had relatively few empty properties (lots without houses) in the dataset we removed these and again ran regressions with both linear and log water clarity. This change significantly improved the model's predicative abilities.[11] We wanted to ensure that the presence of large – and therefore expensive – vacant lakefront property was not having a significant impact upon the value of the amenities within the developed properties. Removing undeveloped properties had significant impact upon the estimated impact of water clarity on property prices.

Finally, we removed the remaining outliers from the dataset and again ran the log and linear regressions.[12], [13] For the regression with log water quality variable, the adjusted R square

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[10] Sale prices were all inflated or deflated to January 2018 using a conventional consumer price index.

[11] Removing empty lots improved the R^2 by .03.

[12] These results can be found in the appendix.

[13] The outlier observations were eliminated based on Interquartile Range (IQR), which is the range between the first and third quartile. Take the sale price variable as an example, IQR is calculated by subtracting the median of the lower half of sale price observations

increased significantly (from 0.41 to 0.54), which indicated that the explanatory power of the regression on the dataset without outliers was superior to the original one.

Additional tests were run to ensure the integrity of the final dataset (with outlier removed). First, a Chow f-test was run to test for possible breaks in the data. Specifically, we wished to test the possibility that properties on reservation lands existed within a separate market from properties just outside the reservation. That is, we wanted to see if properties on the reservation were notably different from properties off the reservation in terms of their market prices for a given set of attributes. Our test suggested that this was not the case and that properties within the reservation were not statistically different (in terms of sales price) from those not within the reservation. Indeed, we found more significant breaks between properties in far Eastern Vilas County, WI and the rest of the study area (discussed below).

We also wanted to ensure that the final dataset did not exhibit any significant multicolinearity across the variables that impact the student results. (See table below.) This was done to ensure that we had good sampling within the dataset. In particular we wanted to ensure that there existed no significant correlation between water clarity and the various housing and locational attributes. For example: It might have been the case that higher property values on lakes with clearer water are worth more because, in general, the houses on those lakes are nicer, bigger, etc… than houses on lakes with reduced clarity. We found that, within the dataset, this is not the case. **Within the dataset, we found very little to no correlation between housing attributes and water clarity.** (See correlation matrices below.) Moreover, we did find correlations between variables where they might be expected to exist. For example, properties with more bedrooms also have more bathrooms, more garage bays, and have a larger square footage of living area. Similarly, properties with larger living areas were correlated with properties having more bedrooms and bathrooms.

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from the median of the upper half of sale price observations. The properties with sale price further than 1.5*IQR from the mean sale price are identified as outliers and eliminated from the data. The outliers in leaving area (LVAREA), the number of bedrooms (BED), the number of bathrooms (BATH) and the number of garages (GARAGE) are cleaned using the same method.

	AIRPORT__KM_	BATH	BED	BSMNT	C_PRICE	DECK
AIRPORT__KM_	1.000000	-0.197291	-0.201463	-0.092650	-0.194846	-0.031510
BATH	-0.197291	1.000000	0.641422	0.355385	0.555830	0.302373
BED	-0.201463	0.641422	1.000000	0.218721	0.389583	0.198173
BSMNT	-0.092650	0.355385	0.218721	1.000000	0.308414	0.194715
C_PRICE	-0.194846	0.555830	0.389583	0.308414	1.000000	0.238093
DECK	-0.031510	0.302373	0.198173	0.194715	0.238093	1.000000
FIRE	-0.153999	0.340060	0.274216	0.273662	0.274450	0.183370
FRONTAGE	-0.015821	0.074892	0.235552	0.048099	0.093443	0.033525
HEAT	-0.092948	0.178267	0.190070	0.282952	0.082146	0.266198
GARAGE	-0.002030	0.493329	0.394848	0.261412	0.290237	0.216704
LKAREA__HECTARES_	0.305830	-0.089351	0.005097	-0.164269	-0.037093	0.021236
LN_WC_M	0.021899	0.066652	0.002010	0.006601	0.305573	0.141704
LOT_SZ__HECTARES_	-0.065514	0.116902	0.129368	0.063957	0.082041	-0.022886
LVAREA__SQM_	-0.139229	0.726234	0.559960	0.394481	0.676668	0.325153
MEDICAL__KM_	0.426632	-0.229557	-0.136151	-0.106945	-0.234389	-0.115739
SEPTIC	-0.363996	0.101102	0.048662	0.217119	0.137141	0.196631
STORY	0.017016	0.419807	0.331804	0.123722	0.279172	0.221018
TAXRT	-0.183411	0.030362	0.058838	-0.028964	-0.053983	0.007025
WC_MEAN__M_	0.013758	0.073199	0.022109	0.026879	0.275762	0.121212

Table 1. Correlation matrix for all variables

	FIRE	FRONTAGE	HEAT	GARAGE	LKAREA__HE	LN_WC_M	LOT_SZ__HE
AIRPORT__KM_	-0.153999	-0.015821	-0.092948	-0.002030	0.305830	0.021899	-0.065514
BATH	0.340060	0.074892	0.178267	0.493329	-0.089351	0.066652	0.116902
BED	0.274216	0.235552	0.190070	0.394848	0.005097	0.002010	0.129368
BSMNT	0.273662	0.048099	0.282952	0.261412	-0.164269	0.006601	0.063957
C_PRICE	0.274450	0.093443	0.082146	0.290237	-0.037093	0.305573	0.082041
DECK	0.183370	0.033525	0.266198	0.216704	0.021236	0.141704	-0.022886
FIRE	1.000000	0.010413	0.264338	0.241261	-0.103465	0.003664	0.006584
FRONTAGE	0.010413	1.000000	0.036603	-0.038366	0.037524	0.095058	0.416533
HEAT	0.264338	0.036603	1.000000	0.232547	-0.105883	-0.097244	0.010031
GARAGE	0.241261	-0.038366	0.232547	1.000000	-0.062497	-0.057243	0.089612
LKAREA__HECTARES_	-0.103465	0.037524	-0.105883	-0.062497	1.000000	0.104035	-0.007028
LN_WC_M	0.003664	0.095058	-0.097244	-0.057243	0.104035	1.000000	0.005444
LOT_SZ__HECTARES_	0.006584	0.416533	0.010031	0.089612	-0.007028	0.005444	1.000000
LVAREA__SQM_	0.437949	0.144767	0.128472	0.378639	-0.129069	0.134332	0.168188
MEDICAL__KM_	-0.112087	0.075698	-0.071153	-0.077411	0.220309	-0.187302	0.012033
SEPTIC	0.227656	0.060978	0.172651	0.009584	-0.379143	0.190939	0.036304
STORY	0.281886	0.202030	0.135841	0.170413	0.119181	0.077385	0.163226
TAXRT	-0.027733	0.003707	-0.029021	-0.046069	-0.025524	0.158624	-0.051478
WC_MEAN__M_	-0.012512	0.111422	-0.086627	-0.052865	0.110909	0.950765	0.020516

Table 1 continued

	LVAREA__SQ	MEDICAL__K	SEPTIC	STORY	TAXRT	WC_MEAN__
AIRPORT__KM_	-0.139229	0.426632	-0.363996	0.017016	-0.183411	0.013758
BATH	0.726234	-0.229557	0.101102	0.419807	0.030362	0.073199
BED	0.559960	-0.136151	0.048662	0.331804	0.058838	0.022109
BSMNT	0.394481	-0.106945	0.217119	0.123722	-0.028964	0.026879
C_PRICE	0.676668	-0.234389	0.137141	0.279172	-0.053983	0.275762
DECK	0.325153	-0.115739	0.196631	0.221018	0.007025	0.121212
FIRE	0.437949	-0.112087	0.227656	0.281886	-0.027733	-0.012512
FRONTAGE	0.144767	0.075698	0.060978	0.202030	0.003707	0.111422
HEAT	0.128472	-0.071153	0.172651	0.135841	-0.029021	-0.086627
GARAGE	0.378639	-0.077411	0.009584	0.170413	-0.046069	-0.052865
LKAREA__HECTARES_	-0.129069	0.220309	-0.379143	0.119181	-0.025524	0.110909
LN_WC_M	0.134332	-0.187302	0.190939	0.077385	0.158624	0.950765
LOT_SZ__HECTARES_	0.168188	0.012033	0.036304	0.163226	-0.051478	0.020516
LVAREA__SQM_	1.000000	-0.195587	0.136261	0.426403	-0.029353	0.120338
MEDICAL__KM_	-0.195587	1.000000	-0.328443	-0.086302	-0.140091	-0.178273
SEPTIC	0.136261	-0.328443	1.000000	-0.021703	0.185072	0.204213
STORY	0.426403	-0.086302	-0.021703	1.000000	-0.013820	0.077825
TAXRT	-0.029353	-0.140091	0.185072	-0.013820	1.000000	0.193185
WC_MEAN__M_	0.120338	-0.178273	0.204213	0.077825	0.193185	1.000000

Table 1 continued

Having tested the dataset to ensure integrity. The final regression output (with all outlier removed) was first used to construct a statistically average valuation for the study area – excluding and value attributable to water quality. This allows for variation between lakes in terms of the types of properties that exist on the lake.[14] One way of thinking about this would be the average value of the set of houses on a given lake within the study – if the lake was not there. We then calculate the expected price of the mean property in our study area. The expected value for the mean property price – excluding the value attributable to the presence of the lake was estimated to be $251,493.00. This accomplished by taking the sum of the mean value (for each lake) of each of the above variables times the estimated coefficient for that variable. To this the estimated constant term of the regression was added to complete the picture.

a = Estimated value of c + (mean value of a * est. coefficient of a) + (mean value of b * est. coefficient of b) + …. + (mean value of x * est. coefficient of x)

From this we can add back in the observed water quality. This allows us to estimate what the average house, on a given lake, should sell for – given all its attributes.

Est. Price = a + (Log of Water Quality on Lake x * estimated log coefficient for water quality)

The table below (Table 1) gives the values for used for each lake to compute the estimated value attributable to water quality. The 'WC Mean (m)' columns are the mean values for water clarity on any given lake in meters. The 'Current Water Value' columns represent the value added to the average house resulting from the presence of the lake at existing clarity. This value is obtained by multiplying Log of WC Mean (m) by the estimated log coefficient for water clarity (66,262.82).

Property Value Impacts

From the above equation we can change the water clarity to any hypothetical situation we might wish to estimate the value attributable to water quality on a given lake with that alternative water quality. (This is the 'second stage' equation mentioned in an earlier section of the study.) These values are represented in the right-side columns. Starting with the first row, we find that on Anvil Lake the presence of the lake adds $101,000 to the value of the average home on that lake. If the water clarity on Anvil lake could be improved by 1 meter we estimate that the presence of the lake would add $114,000 to the value of

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[14] For example: Some of the lakes in the study area are highly developed with large high value properties on them. Other lakes are not nearly as developed in all aspects. Creating different statistical pictures for each lake allows us to account for these differences.

the average house (or a roughly $13,000 improvement in value). If the water clarity could be improved by 2 meters we estimate that the lake would add $125,000 in value to the average house (or an additional $24,000 in value).

It will be noted that these changes in value vary widely across the lakes in the study area. This is because improvements in clarity in lakes where clarity is already high produce relatively small gains in value while improvements in lakes with very poor existing clarity results in larger gains in valuation. We estimate that, across the study area, a 1 meter of improved clarity would increase average property values between eight (8) thousand dollars on Black Oak Lake and thirty-two (32) thousand dollars on McCormick Lake. Of course, the causes of and costs associated with improving lake clarity are unique to the lake as such these results alone cannot ensure that the cost/benefits of mitigation are always favorable.

Lake 2017 (or most recent)	LKAREA (Hectares)	WC Mean (m)	Current Water Value	Plus 1 Meter	Plus 2 Meters	Value Increase 1	Value Increase 2
Anvil Lake	152.57	3.60	101,120.79	114,155.37	125,042.56	13,034.58	23,921.76
Big Lake	341.96	1.02	46,589.22	73,237.43	92,190.26	26,648.21	45,601.04
Big Saint Germain	656.40	3.09	93,334.16	107,828.02	119,713.60	14,493.86	26,379.43
Big Stone	245.64	0.89	42,181.38	70,321.85	90,012.02	28,140.47	47,830.65
Black Oak	228.24	6.70	135,257.02	143,347.88	150,557.47	8,090.87	15,300.45
Blue	178.47	5.65	125,542.66	134,825.33	142,965.96	9,282.68	17,423.31
Boom	147.71	1.05	47,566.09	73,892.43	92,682.92	26,326.34	45,116.84
Buckskin	259.81	2.70	86,693.82	102,545.86	115,328.20	15,852.03	28,634.37
Catfish Lake	395.78	1.46	59,647.23	82,249.96	99,072.77	22,602.73	39,425.54
Cranberry Lake	373.93	1.30	55,190.91	79,112.67	96,651.94	23,921.76	41,461.04
Crawling Stone Lake	600.15	4.60	114,155.37	125,042.56	134,390.82	10,887.18	20,235.45
Crescent	249.29	3.48	99,369.25	112,720.02	123,826.69	13,350.77	24,457.44
Deer	76.08	1.20	52,245.41	77,073.65	95,092.75	24,828.24	42,847.34
Fifth Lake	96.32	0.73	36,320.07	66,547.86	87,228.92	30,227.79	50,908.85
Flambeau Lake	471.86	5.68	125,840.91	135,084.68	143,195.38	9,243.77	17,354.47
George	179.28	1.06	47,888.54	74,109.33	92,846.34	26,220.79	44,957.80
Hancock	104.81	1.65	64,577.07	85,792.27	101,837.16	21,215.20	37,260.09
Indian	143.26	2.74	87,406.33	103,107.41	115,791.58	15,701.08	28,385.24
Island	123.43	2.06	74,109.33	92,846.34	107,436.32	18,737.01	33,326.99
Kawaguesaga Lake	283.28	3.48	99,369.25	112,720.02	123,826.69	13,350.77	24,457.44

Table 2. Water clarity for lakes (the latest year)

Lake 2017 (or most recent)	LKAREA (Hectares)	WC Mean (m)	Current Water Value	Plus 1 Meter	Plus 2 Meters	Value Increase 1	Value Increase 2
Kentuck Lake	405.09	2.63	85,428.19	101,551.54	114,509.40	16,123.35	29,081.21
Killarney	118.57	0.70	35,160.92	65,815.66	86,693.82	30,654.74	51,532.90
Lake Minocqua	541.87	4.96	118,283.80	128,561.76	137,457.52	10,277.96	19,173.71
Laurel	100.77	0.75	37,081.72	67,031.53	87,583.27	29,949.81	50,501.55
Little Fork Lake	135.97	1.56	62,287.53	84,137.91	100,542.08	21,850.38	38,254.54
Little Saint Germain	393.35	1.43	58,834.18	81,672.92	98,625.55	22,838.74	39,791.38
Little Star Lake	105.22	4.26	110,004.96	121,537.95	131,358.08	11,532.99	21,353.11
Long Lake	244.43	1.35	56,615.97	80,109.12	97,418.00	23,493.15	40,802.03
Lost Lake	220.15	1.50	60,716.01	83,011.61	99,664.41	22,295.60	38,948.40
Manitowish Lake	200.72	2.90	90,182.14	105,307.21	117,613.35	15,125.06	27,431.20
Maple Lake	53.01	4.30	110,506.96	121,960.01	131,722.16	11,453.05	21,215.20
McCormick	45.73	0.60	31,143.77	63,314.88	84,878.29	32,171.12	53,734.52
North Twin Lake	1,161.85	8.70	150,557.47	157,059.03	162,979.29	6,501.57	12,421.82
Oscar-Jenny	40.87	1.65	64,577.07	85,792.27	101,837.16	21,215.20	37,260.09
Otter Lake	70.42	0.90	42,531.05	70,550.74	90,182.14	28,019.69	47,651.10
Papoose Lake	170.78	3.00	91,859.77	106,645.89	118,727.04	14,786.12	26,867.26
Pelican Lake	1,434.61	1.40	58,011.03	81,090.81	98,175.30	23,079.78	40,164.27
Pickerel	235.12	1.62	63,822.65	85,245.40	101,408.27	21,422.75	37,585.62
Planting Ground	408.73	1.30	55,190.91	79,112.67	96,651.94	23,921.76	41,461.04
Plum	427.75	2.94	90,858.30	105,845.93	118,061.07	14,987.63	27,202.77

Table 2 continued

Lake 2017 (or most recent)	LKAREA (Hectares)	WC Mean (m)	Current Water Value	Plus 1 Meter	Plus 2 Meters	Value Increase 1	Value Increase 2
Presque Isle	471.46	7.35	140,627.03	148,122.34	154,855.32	7,495.31	14,228.28
Scattering Rice	106.43	2.40	81,090.81	98,175.30	111,745.55	17,084.48	30,654.74
Shishebogama	283.28	2.80	88,460.94	103,940.91	116,480.62	15,479.98	28,019.69
Snipe Lake	87.41	2.81	88,635.08	104,078.82	116,594.77	15,443.74	27,959.69
South Turtle Lake	188.58	1.97	72,131.18	91,360.93	106,247.12	19,229.74	34,115.94
South Twin Lake	254.14	3.12	93,818.42	108,217.42	120,039.21	14,399.00	26,220.79
Spectacle Lake	69.20	2.47	82,441.19	99,221.18	112,598.99	16,779.99	30,157.80
Spirit	140.83	3.35	97,418.00	111,129.15	122,483.83	13,711.15	25,065.83
Squash	161.07	4.85	117,049.41	127,506.14	136,535.44	10,456.74	19,486.03
Squaw	297.85	1.16	51,029.54	76,240.15	94,458.65	25,210.60	43,429.11
Squirrel	529.73	2.75	87,583.27	103,247.06	115,906.92	15,663.79	28,323.65
Sugar Camp	210.03	3.70	102,545.86	115,328.20	126,039.01	12,782.34	23,493.15
Tom Doyle	43.71	1.48	60,183.77	82,631.88	99,369.25	22,448.10	39,185.48
Tomahawk	1,401.02	5.38	122,796.14	132,444.38	140,864.68	9,648.23	18,068.53
Towanda Lake	56.25	3.10	93,495.98	107,958.07	119,822.31	14,462.10	26,326.34
Two Sisters	290.97	4.43	112,051.61	123,261.87	132,847.19	11,210.26	20,795.58
Upper Buckatabon Lake	199.51	2.05	73,892.43	92,682.92	107,305.23	18,790.50	33,412.81
Virgin Lake	105.62	1.21	52,545.92	77,280.40	95,250.33	24,734.48	42,704.41
White Sand Lake	477.93	4.00	106,645.89	118,727.04	128,941.49	12,081.14	22,295.60
Yellow Birch Lake	77.70	1.43	58,834.18	81,672.92	98,625.55	22,838.74	39,791.38

Table 2 continued

Using this information combined with assessment data we can estimate the total value impact of an improvement in water clarity for any of the lakes within the study area. That is,

Change in lake valuation = Σ (Clarity value change + assessed value of lake property)

From this we can calculate the potential change in tax revenues;[15]

Potential change in tax revenues = local tax rate * Change in lake valuation

Using the assessed values for Anvil Lake in Vilas County, WI we can get an idea about the kind of numbers that are in play.[16] Considering only the single family, residential properties adjacent to the lake, and using current assessed values a rough total is $27,738,000 (97 properties). ***If water clarity were improved by 1 meter we would expect total valuation on Anvil Lake to rise by \$1,290,423.00 or roughly \$1.3 million.*** These same methods could be applied to any of the lakes in the study area to arrive at the direct benefits associated with improvements in water clarity.

These figures give only the direct benefits associated with the change in water clarity to single family residential homes. On Anvil Lake there also exist a number of commercial enterprises and public facilities that are not considered in these numbers. Furthermore, it is highly likely that other indirect benefits would result from the improvements. For example, several studies have pointed to the correlations between water clarity and tourism.[17] It is highly likely that should water clarity be improved on several of the study area lakes that those areas would experience increased tourism and the associated economic benefits to commercial establishments both on and near the lake.

Extensions

Besides determining the value of water clarity, the study revealed a few additional interesting results that are worth mentioning. First, it should be noted that our results show that the property tax rate has a negative and statistically significant impact on property prices. This is consistent with what we have found in previous studies and what has

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[15] The word "potential" is used here because realized tax revenues are subject to a variety of constraints that are beyond the scope of this study. These include but are not limited to: State levy limits, changes in the total County assessment, and the willingness of local officials to levy taxes to the full potential.

[16] Anvil Lake is a small lake in Eastern Vilas County with relatively good water clarity (3.6 meters on average). **These figures therefore may be seen as the very low end of potential changes in valuation**.

[17] For recent examples see Lee and Lee 2015 and Farr, et. Al. 2016.

generally been shown to be the case in the literature. This is worth mentioning for at least two reasons: First, policy makers should be aware of the fact that rising property taxes lower property values – as such there is a 'trade-off' always present in terms of actual tax revenues raised. Second, in terms of this study, rising property values do not necessarily mean rising tax rates but it does imply a possibility of an increased total tax levy. Although the tax rate may increase an increased levy is almost certain to have a similar effect upon property prices. As such, policy makers should be aware that there is a possible dynamic at play that may cause property values to not fully rise to the expected extend. To explain: If property owners and potential buyers anticipate larger tax payment resulting from improved valuations (which in turn are the result of improved water clarity) the higher expected tax payments may reduce some of the willingness to pay for the property.

Second, it should be noted that the AIRPORT_KM variable was found to be significant and negative. Initial regression results suggest that moving a given property 1 km (additional driving distance) further away from a public airport reduces the average property value by $2,300. The airports within the study are all small regional airport catering mostly to private and corporate aircraft. Although there are a few (small craft) passenger flights into the region daily they the airports likely do not exhibit the negative externalities that are generally associated with larger airports (noise, air pollution, etc…). Furthermore, in virtually all cases within the study area the public airports exist in areas that also offer a wide variety of other 'city' type amenities such as grocery stores, restaurants, retail shops, theaters, etc… We therefore believe that this variable is acting as a general proxy for the value of 'city' amenities. This is noteworthy because it suggests that even in remote areas, where solitude undoubtedly carries a positive value, access to goods and services is valuable to people. Sounds public policy – if we wish to retain property values – should strive to ensure access to these population centers.

Third, the large number of lakes and the large geographic area of the study area is a potential source of concern. Initially, there some speculation that land and properties within the Lac du Flambeau reservation may be statistically distinct from the remainder of the study area. Testing however, showed this to not be the case. The valuation of property attributes within the reservation lands were not meaningfully different from properties in the surrounding communities. We did note that there were significant variations in the average propriety values within different communities within the study area – most significantly Eastern Vilas County. These disparities create a potential source of concern as distinct markets (if that is indeed the case here) may have distinct willingness to pay for water clarity. However, given the already small size of the dataset we did not attempt to formally subdivide the study area in order to address this potential problem as doing so would create more statistical problems than they would resolve.

Finally following up on Steinnes' (1992) and others work regarding subjective versus objective measures of water clarity work several regressions were run using the subjective measures of water clarity from the Wisconsin Department of Natural Resources reports. We were not able to derive statistical significance with any of the abovementioned models. As such we can say that there was any clear connection between subjective water perception and property prices. We speculate that this inconsistency with some studies in

the literature may be due to the way this data is collected. Being a simple scale from 1 – 5, subjectively determined, may make it difficult for individuals collecting the data to make an evaluation that corresponds to the valuations being made by other data reporters in different locations. Consistent with some studies in the literature we found that the subjective measures of water clarity were unreliable in their ability to predict property prices. Our findings reinforce the prevailing notion that objective measures of water clarity remain the most reliable means to evaluate the market value of water clarity.

Conclusions

There exists a clear economic rationale for the improvement of water clarity on several Northern Wisconsin lakes. **Using a two-stage hedonic model we have estimated that a one (1) meter improvement in water clarity within the study area would increase the average property prices from $8,090 to $32,171.** The variation is largely dependent upon existing water clarity and the degree to which the lake is already economically developed.

On lakes with low water clarity – such as McCormick Lake, Killarney Lake, and Fifth Lake average residential properties would see an improvement in sale price approximately $30,000. The figures for these lakes are much higher than for others within the study area because the willingness to pay for given improvements is likely higher on lakes where clarity is poor. That is, people are likely to pay more for a 2 meters improvement in clarity when the current level is 1 meter than they would if it were 5 meters.

These differences in these increases are also dependent upon the existing level of economic development on the lake. For example, McCormick Lake would be expected to experience a greater gain in property values than Fifth Lake even though Fifth Lake's clarity is worse. The community surrounding Fifth Lake is more developed when compared to McCormick Lake. Fifth lake is a short distance from Rhinelander, Wisconsin – the largest community in the study area. Therefore, any changes to the entire property picture can be expected to have a smaller marginal component.

Thus, taken in sum we conclude that the marginal economic benefits to improvements in clarity are most significant when applied to lakes with low existing clarity and even more so when they are applied to lakes with low clarity and when the surrounding areas are minimally developed. These results reinforce and support the importance of these lakes to the community and should bolster efforts to maintain lake water quality.

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Appendix

Attributes (Predictor variables)	Denotation
Distance from the Nearest Public Airport in Kilometer	AIRPORT__KM_
Distance from the Nearest Emergency Room in Kilometer	MEDICAL__KM_
Number of Bathrooms	BATH
Number of Bedrooms	BED
Number of Garages	GARAGE
Basement (Yes or No)	BSMNT
Deck (Yes or No)	DECK
Fireplace (Yes or No)	FIRE
Length of the Lake Frontage	FRONTAGE
Lake Area in Hectare	LKAREA__HECTARES_
Lot Size in Hectare	LOT_SZ__HECTARES_
Living Area in Square Meter	LVAREA__SQM_
Tax Rate (Mill Rate)	TAXRT
Water Clarity in Meter	WC_MEAN__M_
Log of Water Clarity in Meter	LNWC__M_

Table 1. Predictor variables and their denotation for hedonic model

Dependent Variable: C_PRICE
Method: Least Squares
Date: 08/12/18   Time: 13:22
Sample (adjusted): 1 272
Included observations: 271 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	197537.1	55851.99	3.536796	0.0005
AIRPORT__KM_	-2296.145	882.1211	-2.602981	0.0098
BATH	25498.15	14646.15	1.740946	0.0829
BED	-6278.887	11260.54	-0.557601	0.5776
BSMNT	20938.93	18148.12	1.153780	0.2497
DECK	-12107.61	18944.67	-0.639104	0.5233
FIRE	-20732.41	19794.20	-1.047398	0.2959
FRONTAGE	8.278086	43.96812	0.188275	0.8508
GARAGE	7159.312	7789.361	0.919114	0.3589
LKAREA__HECTARES_	30.99407	20.57208	1.506608	0.1331
LOT_SZ__HECTARES_	-15991.68	15605.00	-1.024779	0.3064
LVAREA__SQM_	1081.990	124.9296	8.660803	0.0000
MEDICAL__KM_	-826.5690	879.2756	-0.940057	0.3481
TAXRT	-8556.150	4028.356	-2.123981	0.0346
WC_MEAN__M_	23235.59	5311.905	4.374247	0.0000

R-squared	0.532946	Mean dependent var		379422.1
Adjusted R-squared	0.507404	S.D. dependent var		184816.9
S.E. of regression	129714.1	Akaike info criterion		26.43781
Sum squared resid	4.31E+12	Schwarz criterion		26.63719
Log likelihood	-3567.324	Hannan-Quinn criter.		26.51787
F-statistic	20.86547	Durbin-Watson stat		1.604016
Prob(F-statistic)	0.000000			

Figure 1. Regression result for the no outlier dataset with linear water clarity

Dependent Variable: C_PRICE
Method: Least Squares
Date: 08/12/18   Time: 13:32
Sample (adjusted): 1 272
Included observations: 271 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	131483.3	58697.14	2.240029	0.0259
AIRPORT__KM_	-2299.989	874.7559	-2.629293	0.0091
BATH	25830.03	14524.65	1.778358	0.0765
BED	-4515.022	11196.88	-0.403239	0.6871
BSMNT	23687.46	18010.43	1.315208	0.1896
DECK	-15516.91	18839.20	-0.823650	0.4109
FIRE	-21484.57	19613.53	-1.095396	0.2744
FRONTAGE	7.955174	43.56782	0.182593	0.8553
GARAGE	7603.978	7727.504	0.984015	0.3260
LKAREA__HECTARES_	29.79712	20.39170	1.461238	0.1452
LOT_SZ__HECTARES_	-15320.24	15478.26	-0.989791	0.3232
LVAREA__SQM_	1058.963	124.3863	8.513506	0.0000
MEDICAL__KM_	-707.5413	873.8406	-0.809691	0.4189
TAXRT	-7954.532	3969.043	-2.004144	0.0461
LN_WC_M	66238.54	13589.34	4.874301	0.0000

R-squared	0.540667	Mean dependent var		379422.1
Adjusted R-squared	0.515547	S.D. dependent var		184816.9
S.E. of regression	128637.5	Akaike info criterion		26.42114
Sum squared resid	4.24E+12	Schwarz criterion		26.62052
Log likelihood	-3565.065	Hannan-Quinn criter.		26.50120
F-statistic	21.52357	Durbin-Watson stat		1.613126
Prob(F-statistic)	0.000000			

Figure 2. Regression result for the no outlier dataset with log water clarity

```
Dependent Variable: C_PRICE
Method: Least Squares
Date: 08/12/18   Time: 13:36
Sample: 1 287
Included observations: 286
```

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	87660.52	89950.93	0.974537	0.3307
AIRPORT__KM_	-2640.956	1401.394	-1.884520	0.0606
BATH	65067.07	22507.62	2.890890	0.0042
BED	-20148.09	17785.15	-1.132860	0.2583
BSMNT	-5604.182	29519.29	-0.189848	0.8496
DECK	-44466.24	30587.31	-1.453748	0.1472
FIRE	-39467.71	32320.61	-1.221131	0.2231
FRONTAGE	110.8731	65.64820	1.688898	0.0924
GARAGE	37064.40	12067.29	3.071476	0.0023
LKAREA__ARCES_	18.63559	13.32184	1.398875	0.1630
LOT_SZ__HECTARES_	1391.546	5543.493	0.251023	0.8020
LVAREA__SQM_	1316.560	188.7628	6.974680	0.0000
MEDICAL__KM_	739.6732	1429.310	0.517504	0.6052
TAXRT	-11435.55	6582.137	-1.737362	0.0835
WC_MEAN__M_	25892.67	8713.974	2.971397	0.0032

R-squared	0.501239	Mean dependent var		424565.1
Adjusted R-squared	0.475473	S.D. dependent var		299282.0
S.E. of regression	216752.7	Akaike info criterion		27.46192
Sum squared resid	1.27E+13	Schwarz criterion		27.65367
Log likelihood	-3912.055	Hannan-Quinn criter.		27.53878
F-statistic	19.45334	Durbin-Watson stat		1.851955
Prob(F-statistic)	0.000000			

Figure 3. Regression result for the no vacant dataset with linear water clarity

```
Dependent Variable: C_PRICE
Method: Least Squares
Date: 08/12/18   Time: 13:37
Sample: 1 287
Included observations: 286
```

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	11402.99	95152.90	0.119839	0.9047
AIRPORT__KM_	-2669.520	1395.283	-1.913247	0.0568
BATH	65120.61	22407.14	2.906243	0.0040
BED	-18143.56	17752.78	-1.022012	0.3077
BSMNT	-2820.910	29402.25	-0.095942	0.9236
DECK	-48513.88	30532.11	-1.588946	0.1132
FIRE	-40507.92	32151.25	-1.259917	0.2088
FRONTAGE	109.0806	65.32262	1.669875	0.0961
GARAGE	37745.13	12021.46	3.139812	0.0019
LKAREA__ARCES_	18.21338	13.22894	1.376783	0.1697
LOT_SZ__HECTARES_	1341.684	5517.180	0.243183	0.8080
LVAREA__SQM_	1295.584	188.3581	6.878300	0.0000
MEDICAL__KM_	899.9131	1426.295	0.630944	0.5286
TAXRT	-10754.00	6501.692	-1.654031	0.0993
LN_WC_M	75488.25	22422.77	3.366589	0.0009

R-squared	0.505664	Mean dependent var		424565.1
Adjusted R-squared	0.480126	S.D. dependent var		299282.0
S.E. of regression	215789.1	Akaike info criterion		27.45301
Sum squared resid	1.26E+13	Schwarz criterion		27.64476
Log likelihood	-3910.781	Hannan-Quinn criter.		27.52987
F-statistic	19.80073	Durbin-Watson stat		1.861174
Prob(F-statistic)	0.000000			

Figure 4. Regression result for the no vacant dataset with log water clarity

```
Dependent Variable: C_PRICE
Method: Least Squares
Date: 08/12/18   Time: 13:44
Sample: 1 309
Included observations: 307
```

Variable	Coefficient	Std. Error	t-Statistic	Prob.
AIRPORT__KM_	-2060.020	1434.709	-1.435845	0.1521
BATH	74019.05	26038.45	2.842683	0.0048
BED	-46631.73	19294.92	-2.416788	0.0163
BSMNT	-12410.90	34041.13	-0.364585	0.7157
DECK	-47209.12	34834.50	-1.355240	0.1764
FIRE	-34028.98	36716.47	-0.926804	0.3548
FRONTAGE	230.3763	72.38002	3.182871	0.0016
GARAGE	44226.60	13831.26	3.197584	0.0015
LKAREA__HECTARES_	35.13221	38.07046	0.922821	0.3569
LOT_SZ__HECTARES_	67.18061	6235.853	0.010773	0.9914
LVAREA__SQM_	1207.307	214.8542	5.619192	0.0000
MEDICAL__KM_	3481.602	1449.679	2.401637	0.0169
TAXRT	-4228.617	4996.466	-0.846322	0.3981
WC_MEAN__M_	32831.92	9681.730	3.391122	0.0008

R-squared	0.393931	Mean dependent var		420439.3
Adjusted R-squared	0.367040	S.D. dependent var		316805.5
S.E. of regression	252046.5	Akaike info criterion		27.75715
Sum squared resid	1.86E+13	Schwarz criterion		27.92710
Log likelihood	-4246.722	Hannan-Quinn criter.		27.82511
Durbin-Watson stat	1.952401			

Figure 5. Regression result for the full dataset with linear water clarity

```
Dependent Variable: C_PRICE
Method: Least Squares
Date: 08/12/18   Time: 13:44
Sample: 1 309
Included observations: 307
```

Variable	Coefficient	Std. Error	t-Statistic	Prob.
AIRPORT__KM_	-2763.227	1440.985	-1.917596	0.0561
BATH	73251.82	25777.75	2.841669	0.0048
BED	-44378.38	19091.09	-2.324560	0.0208
BSMNT	-10553.08	33699.33	-0.313154	0.7544
DECK	-54483.50	34592.09	-1.575028	0.1163
FIRE	-39051.39	36300.38	-1.075785	0.2829
FRONTAGE	223.9782	71.61117	3.127699	0.0019
GARAGE	45202.27	13693.93	3.300897	0.0011
LKAREA__HECTARES_	34.13081	37.48709	0.910468	0.3633
LOT_SZ__HECTARES_	-576.3766	6171.074	-0.093400	0.9256
LVAREA__SQM_	1157.975	213.4935	5.423934	0.0000
MEDICAL__KM_	3108.521	1426.170	2.179629	0.0301
TAXRT	-9437.336	5373.132	-1.756394	0.0801
LN_WC_M	95652.29	22714.46	4.211075	0.0000

R-squared	0.406089	Mean dependent var		420439.3
Adjusted R-squared	0.379738	S.D. dependent var		316805.5
S.E. of regression	249505.7	Akaike info criterion		27.73688
Sum squared resid	1.82E+13	Schwarz criterion		27.90683
Log likelihood	-4243.611	Hannan-Quinn criter.		27.80484
Durbin-Watson stat	1.977158			

Figure 6. Regression result for the full dataset with log water clarity

Lake	LKAREA (Hectares)	WC Mean (m)	Year	Current Water Value	Plus 1 Meter	Plus 2 Meters	Value Increase 1	Value Increase 2
Anvil Lake	152.57	3.50	2015	99,664.41	112,961.42	124,030.89	13,297.01	24,366.48
Anvil Lake	152.57	3.50	2016	99,664.41	112,961.42	124,030.89	13,297.01	24,366.48
Anvil Lake	152.57	3.60	2017	101,120.79	114,155.37	125,042.56	13,034.58	23,921.76
Big Lake	341.96	1.01	2016	46,260.38	73,017.66	92,025.22	26,757.28	45,764.85
Big Lake	341.96	1.02	2017	46,589.22	73,237.43	92,190.26	26,648.21	45,601.04
Big Saint Germain	656.40	3.24	2015	95,720.84	109,752.53	121,325.91	14,031.70	25,605.07
Big Saint Germain	656.40	2.63	2016	85,428.19	101,551.54	114,509.40	16,123.35	29,081.21
Big Saint Germain	656.40	3.09	2017	93,334.16	107,828.02	119,713.60	14,493.86	26,379.43
Big Stone	245.64	0.95	2016	44,252.26	71,683.46	91,026.27	27,431.20	46,774.01
Big Stone	245.64	0.89	2017	42,181.38	70,321.85	90,012.02	28,140.47	47,830.65
Big Stone	245.64	1.05	2018	47,566.09	73,892.43	92,682.92	26,326.34	45,116.84
Black Oak	228.24	6.70	2017	135,257.02	143,347.88	150,557.47	8,090.87	15,300.45
Blue	178.47	6.18	2015	130,577.70	139,223.53	146,870.37	8,645.84	16,292.68
Blue	178.47	5.65	2017	125,542.66	134,825.33	142,965.96	9,282.68	17,423.31
Boom	147.71	1.30	2015	55,190.91	79,112.67	96,651.94	23,921.76	41,461.04
Boom	147.71	1.23	2016	53,142.89	77,691.97	95,564.37	24,549.09	42,421.48
Boom	147.71	1.05	2017	47,566.09	73,892.43	92,682.92	26,326.34	45,116.84
Buckskin	259.81	2.70	2016	86,693.82	102,545.86	115,328.20	15,852.03	28,634.37
Buckskin	259.81	2.70	2017	86,693.82	102,545.86	115,328.20	15,852.03	28,634.37
Catfish Lake	395.78	1.46	2015	59,647.23	82,249.96	99,072.77	22,602.73	39,425.54
Catfish Lake	395.78	1.46	2016	59,647.23	82,249.96	99,072.77	22,602.73	39,425.54
Catfish Lake	395.78	1.46	2017	59,647.23	82,249.96	99,072.77	22,602.73	39,425.54
Cranberry Lake	373.93	1.30	2016	55,190.91	79,112.67	96,651.94	23,921.76	41,461.04
Cranberry Lake	373.93	1.30	2017	55,190.91	79,112.67	96,651.94	23,921.76	41,461.04
Crawling Stone Lake	600.15	4.70	2016	115,328.20	126,039.01	135,257.02	10,710.81	19,928.82

Table 2. Water clarity for lakes (all years)

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Lake	LKAREA (Hectares)	WC Mean (m)	Year	Current Water Value	Plus 1 Meter	Plus 2 Meters	Value Increase 1	Value Increase 2
Lake Minocqua	541.87	3.36	2016	97,570.15	111,252.89	122,588.10	13,682.74	25,017.95
Lake Minocqua	541.87	4.96	2017	118,283.80	128,561.76	137,457.52	10,277.96	19,173.71
Laurel	100.77	0.75	2017	37,081.72	67,031.53	87,583.27	29,949.81	50,501.55
Little Fork Lake	135.97	1.56	2015	62,287.53	84,137.91	100,542.08	21,850.38	38,254.54
Little Saint Germain	393.35	1.20	2016	52,245.41	77,073.65	95,092.75	24,828.24	42,847.34
Little Saint Germain	393.35	1.43	2017	58,834.18	81,672.92	98,625.55	22,838.74	39,791.38
Little Star Lake	105.22	4.26	2016	110,004.96	121,537.95	131,358.08	11,532.99	21,353.11
Long Lake	244.43	1.65	2015	64,577.07	85,792.27	101,837.16	21,215.20	37,260.09
Long Lake	45.73	3.79	2016	103,802.72	116,366.28	126,923.18	12,563.56	23,120.46
Long Lake	244.43	1.65	2016	64,577.07	85,792.27	101,837.16	21,215.20	37,260.09
Long Lake	244.43	1.35	2017	56,615.97	80,109.12	97,418.00	23,493.15	40,802.03
Lost Lake	220.15	1.50	2017	60,716.01	83,011.61	99,664.41	22,295.60	38,948.40
Manitowish Lake	200.72	2.50	2015	83,011.61	99,664.41	112,961.42	16,652.80	29,949.81
Manitowish Lake	200.72	2.50	2016	83,011.61	99,664.41	112,961.42	16,652.80	29,949.81
Manitowish Lake	200.72	2.50	2016	83,011.61	99,664.41	112,961.42	16,652.80	29,949.81
Manitowish Lake	200.72	2.90	2017	90,182.14	105,307.21	117,613.35	15,125.06	27,431.20
Maple Lake	53.01	4.30	2017	110,506.96	121,960.01	131,722.16	11,453.05	21,215.20
McCormick	45.73	0.60	2015	31,143.77	63,314.88	84,878.29	32,171.12	53,734.52
McCormick	45.73	0.60	2016	31,143.77	63,314.88	84,878.29	32,171.12	53,734.52
McCormick	45.73	0.60	2017	31,143.77	63,314.88	84,878.29	32,171.12	53,734.52
North Twin Lake	1,161.85	4.30	2015	110,506.96	121,960.01	131,722.16	11,453.05	21,215.20
North Twin Lake	1,161.85	3.14	2016	94,139.31	108,475.75	120,255.41	14,336.44	26,116.10
North Twin Lake	1,161.85	8.70	2017	150,557.47	157,059.03	162,979.29	6,501.57	12,421.82
Oscar-Jenny	40.87	1.65	2016	64,577.07	85,792.27	101,837.16	21,215.20	37,260.09
Otter Lake	70.42	1.30	2015	55,190.91	79,112.67	96,651.94	23,921.76	41,461.04

Lake	LKAREA (Hectares)	WC Mean (m)	Year	Current Water Value	Plus 1 Meter	Plus 2 Meters	Value Increase 1	Value Increase 2
Otter Lake	70.42	1.33	2016	55,907.27	79,612.77	97,036.08	23,705.50	41,128.81
Otter Lake	70.42	0.90	2017	42,531.05	70,550.74	90,182.14	28,019.69	47,651.10
Papoose Lake	170.78	3.00	2017	91,859.77	106,645.89	118,727.04	14,786.12	26,867.26
Pelican Lake	1,434.61	1.58	2015	62,803.20	84,509.14	100,832.07	21,705.94	38,028.87
Pelican Lake	1,434.61	1.68	2016	65,199.26	86,244.58	102,192.45	21,045.32	36,993.19
Pelican Lake	1,434.61	1.40	2017	58,011.03	81,090.81	98,175.30	23,079.78	40,164.27
Pickerel	235.12	1.62	2017	63,822.65	85,245.40	101,408.27	21,422.75	37,585.62
Planting Ground	408.73	1.50	2015	60,716.01	83,011.61	99,664.41	22,295.60	38,948.40
Planting Ground	408.73	1.53	2016	61,506.43	83,577.15	100,104.70	22,070.73	38,598.27
Planting Ground	408.73	1.30	2017	55,190.91	79,112.67	96,651.94	23,921.76	41,461.04
Plum	427.75	2.94	2017	90,858.30	105,845.93	118,061.07	14,987.63	27,202.77
Presque Isle	471.46	7.35	2015	140,627.03	148,122.34	154,855.32	7,495.31	14,228.28
Scattering Rice	106.43	1.22	2016	52,845.08	77,486.51	95,407.54	24,641.43	42,562.46
Scattering Rice	106.43	2.40	2017	81,090.81	98,175.30	111,745.55	17,084.48	30,654.74
Shishebogama	283.28	2.00	2016	72,797.15	91,859.77	106,645.89	19,062.63	33,848.75
Shishebogama	283.28	2.80	2017	88,460.94	103,940.91	116,480.62	15,479.98	28,019.69
Snipe Lake	87.41	2.40	2016	81,090.81	98,175.30	111,745.55	17,084.48	30,654.74
Snipe Lake	87.41	2.81	2017	88,635.08	104,078.82	116,594.77	15,443.74	27,959.69
South Turtle Lake	188.58	2.27	2015	78,507.53	96,188.03	110,130.82	17,680.50	31,623.29
South Turtle Lake	188.58	1.97	2017	72,131.18	91,360.93	106,247.12	19,229.74	34,115.94
South Twin Lake	254.14	3.12	2016	93,818.42	108,217.42	120,039.21	14,399.00	26,220.79
Spectacle Lake	69.20	2.47	2016	82,441.19	99,221.18	112,598.99	16,779.99	30,157.80
Spirit	140.83	3.35	2017	97,418.00	111,129.15	122,483.83	13,711.15	25,065.83
Squash	161.07	5.50	2015	124,030.89	133,513.16	141,806.82	9,482.27	17,775.93
Squash	161.07	5.67	2016	125,741.64	134,998.34	143,119.00	9,256.70	17,377.35

Lake	LKAREA (Hectares)	WC Mean (m)	Year	Current Water Value	Plus 1 Meter	Plus 2 Meters	Value Increase 1	Value Increase 2
Squash	161.07	4.85	2017	117,049.41	127,506.14	136,535.44	10,456.74	19,486.03
Squaw	297.85	1.16	2017	51,029.54	76,240.15	94,458.65	25,210.60	43,429.11
Squirrel	529.73	2.75	2016	87,583.27	103,247.06	115,906.92	15,663.79	28,323.65
Squirrel	529.73	2.75	2017	87,583.27	103,247.06	115,906.92	15,663.79	28,323.65
Sugar Camp	210.03	1.01	2016	46,260.38	73,017.66	92,025.22	26,757.28	45,764.85
Sugar Camp	210.03	3.70	2018	102,545.86	115,328.20	126,039.01	12,782.34	23,493.15
Tom Doyle	43.71	1.27	2016	54,320.92	78,507.53	96,188.03	24,186.60	41,867.10
Tom Doyle	43.71	1.48	2017	60,183.77	82,631.88	99,369.25	22,448.10	39,185.48
Tomahawk	1,401.02	5.48	2015	123,826.69	133,336.22	141,650.72	9,509.53	17,824.03
Tomahawk	1,401.02	5.39	2016	122,899.92	132,534.10	140,943.70	9,634.18	18,043.78
Tomahawk	1,401.02	5.38	2017	122,796.14	132,444.38	140,864.68	9,648.23	18,068.53
Towanda Lake	56.25	3.03	2015	92,354.89	107,042.28	119,057.52	14,687.39	26,702.63
Towanda Lake	56.25	3.24	2016	95,720.84	109,752.53	121,325.91	14,031.70	25,605.07
Towanda Lake	56.25	3.10	2017	93,495.98	107,958.07	119,822.31	14,462.10	26,326.34
Two Sisters	290.97	5.08	2015	119,550.19	129,647.68	138,407.98	10,097.49	18,857.79
Two Sisters	290.97	4.43	2016	112,051.61	123,261.87	132,847.19	11,210.26	20,795.58
Two Sisters	290.97	4.43	2017	112,051.61	123,261.87	132,847.19	11,210.26	20,795.58
Upper Buckatabon Lake	199.51	2.41	2015	81,285.42	98,325.72	111,868.15	17,040.31	30,582.73
Upper Buckatabon Lake	199.51	2.05	2017	73,892.43	92,682.92	107,305.23	18,790.50	33,412.81
Virgin Lake	105.62	1.68	2015	65,323.00	86,334.67	102,263.28	21,011.67	36,940.28
Virgin Lake	105.62	1.21	2017	52,545.92	77,280.40	95,250.33	24,734.48	42,704.41
White Sand Lake	477.93	4.00	2017	106,645.89	118,727.04	128,941.49	12,081.14	22,295.60
Yellow Birch Lake	77.70	1.37	2016	57,177.52	80,503.54	97,721.96	23,326.02	40,544.43
Yellow Birch Lake	77.70	1.43	2017	58,834.18	81,672.92	98,625.55	22,838.74	39,791.38
Yellow Birch Lake	77.70	1.65	2018	64,577.07	85,792.27	101,837.16	21,215.20	37,260.09